

Aspects of the life history and ecology of two wingless grasshoppers, *Eremidium armstrongi* and *Eremidium browni* (Lentulidae), at the Doreen Clark Nature Reserve, KwaZulu-Natal, South Africa

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Abstract

Most grasshopper species have simple and similar life cycles and histories; however, different environmental and ecological factors have different effects on their distribution, sexes, and developmental stages, with effects varying among species. If we are to conserve grasshoppers, we need to understand their ecology and life histories. The aim of this study was to investigate aspects of the life histories and ecology of two recently described co-occurring, congeneric species of wingless grasshoppers, *Eremidium armstrongi* (Brown, 2012) and *Eremidium browni* Otte & Armstrong, 2017, at the Doreen Clark Nature Reserve near Pietermaritzburg, South Africa. These two species have limited extents of occurrence, only being known from an endangered forest type in parts of the midland area of KwaZulu-Natal Province, South Africa, and therefore may need conservation action to ensure their long-term survival. No significant differences in the abundances of the two *Eremidium* grasshoppers were found, but their phenologies differed, with the adults of *E. armstrongi* being present before the adults of *E. browni*, with some overlap in presence over time. The *Eremidium* grasshoppers were only found in the forest and were more abundant in the forest margin. The *Eremidium* grasshoppers fed on soft plants from several families. Information on dietary differences between the species is required to determine whether there is potential competition between them. An adult *E. browni* female kept in an *ex situ* terrarium laid eggs in the soil, and nymphs took approximately two months to hatch.

Keywords

adult densities, adult turnover, competition avoidance, microhabitat selection, sympatric congeners

Introduction

The order Orthoptera is an important element of biodiversity, contributing significantly to the species richness on earth (Bekele 2001). Grasshoppers are considered the most important members of Orthoptera for their contribution to biomass, abundance, and diversity (Mahmood et al. 2004). Grasshoppers are epigeic invertebrates that sometimes form compact groups comprised of several individuals, which can be hoppers and/or winged adults, or they

can be polyphenic (Capinera et al. 1997, Song 2011). The eggs of a mature female are laid in egg pods or clusters in the soil, in the stems of plants, or in rotten wood (Johnsen 1985). Once the egg hatches, the nymph gradually changes into its mature form. Grasshoppers are phytophagous insects (Johnsen 1985), and they can be the primary plant consumers in grassland ecosystems (Gardiner et al. 2005). The nymph and adult display similar feeding patterns. However, both life stages may respond differently to different landscape types at different scales (Bekele 2001).

Biotic and abiotic factors, such as host vegetation, plant diversity, habitat structure, predators, changes in seasonality, light intensity, precipitation, and elevation, influence grasshopper diversity and population dynamics (Bekele 2001, Mahmood et al. 2004, Sirin et al. 2010, Branson 2011, Ely et al. 2011). Grasshoppers are ectotherms, and their body temperature strongly influences most of their physiological processes; their ability to tolerate ambient environmental temperatures and humidity has the potential to determine their richness, spread, ecology, behavior, and the overall fitness of an individual (Willott and Hassall 1998). Therefore, the diversity and abundance of grasshoppers is relatively low in areas dominated by forest, as these habitats are not suitable for most grasshopper species (Sergeev 2011).

The grasshoppers in the family Lentulidae Dirsh, 1956 are wingless. Certain genera in this family, such as *Eremidium*, have species with small distribution ranges that occur in forests in the province of KwaZulu-Natal and elsewhere in South Africa (e.g., Brown 2012, Otte 2015, Otte and Armstrong 2017). Since various forest types and forests are endangered in KwaZulu-Natal due to clearing, logging, other forest products extraction, fire, and alien plant encroachment (Mucina and Rutherford 2006, Jewitt et al. 2016), these endemic grasshopper species are of conservation concern. However, little is known about the life histories and ecology of these species, potentially hampering conservation efforts.

The present study focuses on aspects of the life history and ecology of two species, *Eremidium armstrongi* (Brown, 2012) and *E. browni* (Otte & Armstrong, 2017) found in Doreen Clark Nature Reserve near Pietermaritzburg, South Africa. These grasshoppers

inhabit the Endangered Eastern Mistbelt Forest type (Jewitt 2018) in a restricted area of the midland region of KwaZulu-Natal Province, South Africa. Although these two species may require conservation action for their long-term survival, almost nothing is known about their life history and ecology. The main objectives of this study were to determine the time of year during which adults of each species were present, estimate densities and the number of adult individuals of each species in the sampled habitat area, identify microhabitat features that may explain microhabitat preferences of the species, investigate how far the distribution of *Eremidium* grasshoppers extended into grassland, and, if possible, ascertain how two very similar species can co-occur.

Materials and methods

Study area.—The Doreen Clark Nature Reserve (29°57.85'S, 30°28.92'E; Fig. 1) is in the suburb of Winterskloof, north-west of

Pietermaritzburg, in the KwaZulu-Natal province of South Africa. The vegetation in this protected area of approximately five hectares is the Southern Mistbelt Forest and Midlands Mistbelt Grassland (Fig. 1; Mucina and Rutherford 2006). The greater part of the reserve is covered by forest, containing a genus of conifers known as *Podocarpus* as well as many other genera of angiosperms. The forest meets the grassland at the narrow forest-grassland ecotone, where many insect species can be found, including *E. armstrongi* and *E. browni*. Between the forest margin and the grassland lies a hiking trail, which contributes to the human disturbances experienced by the Doreen Clark Nature Reserve. The study site was situated along the hiking trail, extending approximately 15 m on either side (Fig. 2). At the beginning of the hiking trail, grasses in the grassland were tall and green, reducing in height and becoming drier as the trail moved more towards the west. A small stream runs through the forest. The forest is multistory, with a largely herbaceous understory of forest grasses, sedges, ferns, forbs, etc.



Fig. 1. Study site, Doreen Clark Nature Reserve (including sampling area and section of the foot path).

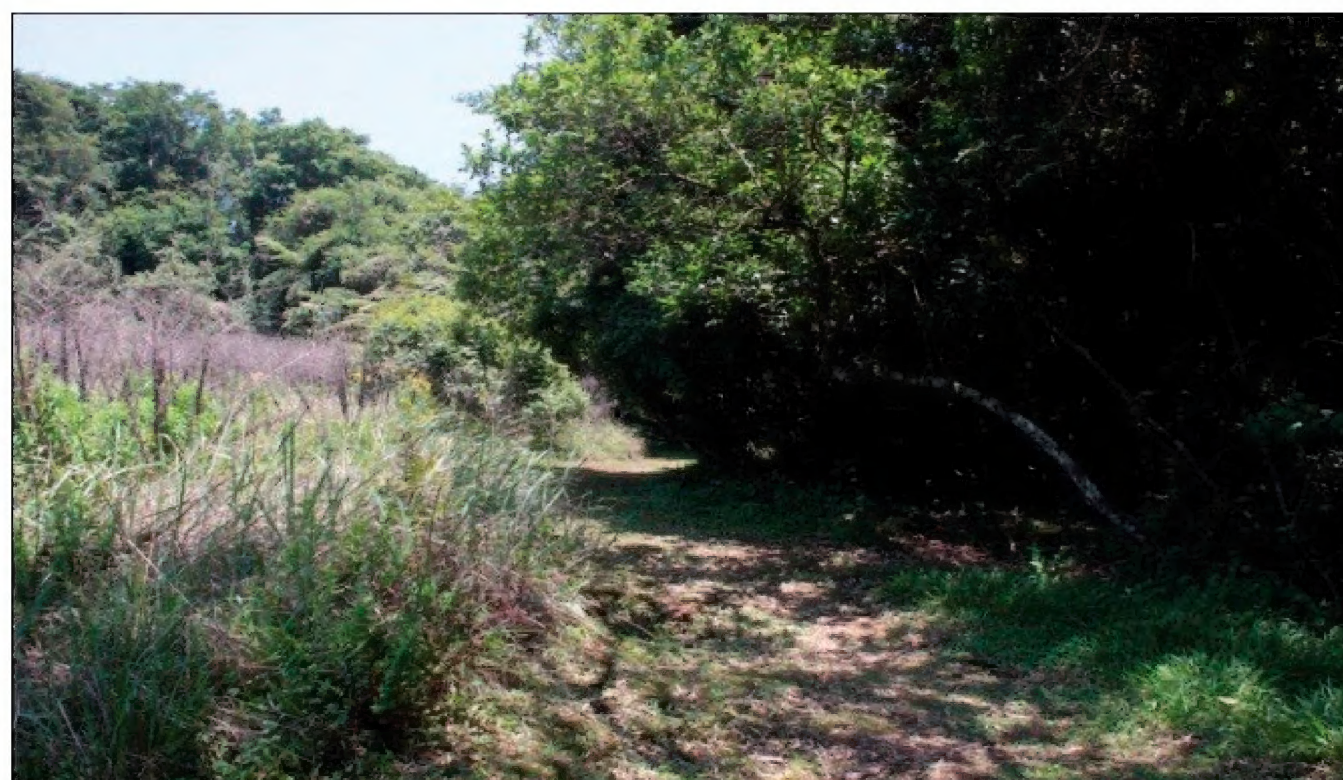


Fig. 2. Hiking trail, with the grasslands (left) and forest margin (right) of the trail.

Estimation of time of year of presence and number of adults in the sampled area.—A quantitative direct count method using quadrats was used (Richards and Waloff 1954, Gardiner et al. 2005, Samways et al. 2010). Twenty-seven 1-m² quadrats (Fig. 3), each made from gardening twine and secured at the corners by 3-in nails, were placed uniformly in the study area on 12 November 2018 and left out in the field for the study period. The quadrats were placed 5 m apart to minimize the probability of double-counting grasshoppers. Twelve quadrats were placed along the forest margin, and the remainder of the quadrats extended into the forest, ending near the stream bank.

Sampling was carried out on 15 days spread out over 3 months (13 November 2018 – 14 January 2019). These months were chosen because previous observations determined that *E. armstrongi* adults were present during October and November, and *E. browni* adults were present in December and January. Sampling days were selected based on weather conditions of temperatures greater than 20°C to ensure that the grasshoppers were active and could be easily seen. On each sampling day, the sequence in which the quadrats were sampled was reversed from that of the previous occasion to reduce bias caused by variation in sampling time. Sampling was carried out between 9 am and midday, local time.

Species turnover with time of year was determined for adult males only because it was difficult to differentiate between nymphs and females of the two species in the field. These data were obtained from the quadrat counts on the total (15) sampling occasions and plotted over time to show the turnover of the species.

The average density per square meter of *E. armstrongi* and *E. browni* observed over the first five sampling occasions (for *E. armstrongi*) and over the last five sampling occasions (for *E. browni*) was calculated from the data. The sampling occasions are given in Table 1. The dates of each sampling occasion were chosen to avoid overlap in the presence of adults of both species. All adult females recorded on a particular sampling occasion were assumed to be of the same species as the males present. The area of the sampling site was calculated using a geographical information system (GIS; QGIS 3.4.15 Madeira) and geographical coordinates collected by a hand-held global positioning system (GPS; Garmin GPSMAP 64).

The average number of individuals of both species at the sampling site was then calculated. Average male to female ratios for *E. armstrongi* and *E. browni* over the five sampling occasions for each were calculated from the raw data.

An independent *t*-test was performed using the statistical package SPSS (IBM Corp. Released 2019. IBM SPSS Statistics Subscription for Windows, Trial Version) to determine if the adult densities of the two species differed significantly within the study area. The assumption of equal variance was tested by performing Levene's Test for equality of variances, and the assumption that the data are normally distributed was tested using the one-sample Kolmogorov-Smirnov test. The assumptions of equality of variances and normal distribution were met ($F = 2.327$, $df = 8$, $p = 0.166$; $\alpha = 5.3177$). Thereafter, an independent samples *t*-test was used to test the null hypothesis that the abundance for *E. armstrongi* did not differ significantly from that of *E. browni* at a significance level of $p < 0.05$.

Identification of microhabitats.—To identify and describe the microhabitats favored by each species, the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974) was used. This assessment was done to see how the variation in vegetation in the 27

Table 1. Number of adult males and females recorded during each sampling occasion, mean ($\pm$ one standard deviation) number of adults per day, estimated mean total number of adults in the sampled area (877 m²), and estimated adult sex ratio.

<i>E. armstrongi</i> (N = 5)			<i>E. browni</i> (N = 5)		
Date	Males	Females	Date	Males	Females
13 Nov 2018	4	7	08 Jan 2019	5	7
20 Nov 2018	5	13	09 Jan 2019	8	8
26 Nov 2018	6	4	10 Jan 2019	6	7
29 Nov 2018	8	10	11 Jan 2019	6	9
01 Dec 2018	6	9	14 Jan 2019	4	7
Total	29	43	Total	29	38
Mean ($\pm$ 1 S.D.)	14.20 ($\pm$ 3.564)		Mean ($\pm$ 1 S.D.)	13.40 ($\pm$ 2.302)	
Mean/m ²	0.53		Mean/m ²	0.50	
Mean/877 m ²	468		Mean/877 m ²	435	
Male:Female	1:1.5		Male:Female	1:1.3	



Fig. 3. Sampling quadrat (A) and female *Eremidium armstrongi* on the boundary of the quadrat (B).

plots relates to the abundance of *E. armstrongi* and *E. browni* in order to determine microhabitat preferences. The Braun-Blanquet scale used is given in Table 2.

The species of all plants found within each quadrat, starting from quadrat 1, was recorded using a labelling system (e.g., P1 = *Plectranthus laxiflorus* Benth.). Thereafter, the vegetation cover of each plant species found within each quadrat was recorded using the Braun-Blanquet scale. To ensure that the feeding and other behavior of the grasshoppers were undisturbed, a specimen of each representative plant species in the sampling quadrats was collected using a hand spade and labelled according to the code assigned to it once sampling was completed. These plants were then pressed and dried and identified to the closest known taxonomic group using two plant field guides (Pooley 1998 and Oudtshoorn 1999) and by comparison with specimens in the Bews Herbarium at the University of KwaZulu-Natal, Pietermaritzburg. The degree of constancy for each plant species was calculated by counting the number of quadrats the plant species occupied.

A simple observation method was undertaken in the field to identify what plant species the grasshoppers fed on. The grasshoppers were observed from a distance. If the plant species was unknown, it was allocated a number and a sample taken for later identification in the laboratory. To determine where eggs were laid and the incubation period, a pair of mature grasshoppers from each species, *E. armstrongi* and *E. browni*, were captured and kept in captivity. A terrarium was created using a fish tank (61 cm × 32 cm × 33 cm) in which soil and plants from the Doreen Clark Nature Reserve were added. Soil was placed at the bottom of the tank to a depth of approximately 5 cm, and the plants were placed in the soil to provide food and shelter. The tank was covered with shade cloth in such a way as air could circulate and placed near a window for sunlight and heat. Water was added to the tank regularly to prevent plants from dying, and fresh food plants were collected as needed from the study site. The grasshoppers were monitored daily.

Distribution of Eremidium grasshoppers into the grassland.—The distribution of the two grasshopper species into the grassland was investigated using a transect sampling method. Strip transects were created using a GPS, starting at the hiking trail and extending into the grassland, with each transect approximately 5 m apart. On each transect, three people sampled: one in the middle and two approximately 1 m away on either side. Sampling was carried out over three days, and only the adults of each species were captured and identified along transects. After identification, each grasshopper was released behind the samplers to avoid resampling the same individuals. The coordinates of each grasshopper identified along the transects were uploaded into GIS software and used to map the extent of their distribution into the grassland.

Table 2. Braun-Blanquet scale.

Symbol/Scale	Vegetation cover
r	Some individuals
+	Many individuals but < 1%
1	1–5%
2	6–25%
3	26–50%
4	51–75%
5	>75%

Results

Period of presence of adults.—On the first five sampling occasions (during the period of 13 November to 01 December 2018), only *E. armstrongi* adult males were present, and during the last five sampling occasions (during the period of 08 to 14 January 2019), only *E. browni* adult males were present. On the intervening five sampling occasions (during the period of 12 to 18 December 2018), both *E. armstrongi* and *E. browni* adult males were present (Fig. 4). The data for both the males of both species show an asymmetrical bell-curve distribution, with the peak value for *E. armstrongi* of 8 males on the fourth sampling occasion (29 November 2018) and with the peak value for *E. browni* of 8 males on the twelfth sampling occasion (09 January 2019).

Estimated number of adult individuals.—The total number of *E. armstrongi* adults recorded over the five days of sampling was 72 individuals, with an average of 14 adult individuals per day, and the total number of *E. browni* adults was 67 individuals, averaging 13 individuals per day (Table 1). The calculated area for the sampling area in the forest margin habitat, as indicated in Fig. 1, was 877 m². *Eremidium armstrongi* had a higher estimated number of adult individuals in the sampled habitat area than *E. browni*, with a difference of 33 individuals (Table 1). The male to female ratio is biased towards females in both species (Table 1), with *E. armstrongi* having a higher female ratio compared to *E. browni*. There is a greater variation of values in the *E. armstrongi* dataset than that of *E. browni* (Table 1). The mean number for *E. armstrongi* is greater than that of *E. browni* (Table 1), but not significantly so ($t = 0.422$, $df = 8$, $p = 0.684$).

Microhabitats.—Over the five sampling occasions, a total of 59 *E. armstrongi* (both sexes combined) were recorded in the 12 quadrats at the margin of the forest and 13 *E. armstrongi* in the 15 quadrats in the forest interior; the respective numbers for *E. browni* were 52 and 15 (Table 3). *E. armstrongi* was observed to occur significantly more than expected in the quadrats at the forest margin ($\chi^2_{1,99} = 13.614$, $p < 0.001$), as was *E. browni* ($\chi^2_{1,94} = 9.743$, $p < 0.002$). The two quadrats with the highest total mean number for both species were quadrats 5 and 17, and two plant species were recorded with high degrees of constancy (Table 3). Quadrat 5 had no bare ground and had more than 75% cover of Poaceae and 6–25% cover of *Centella asiatica* (L.) Urb. This quadrat was on the

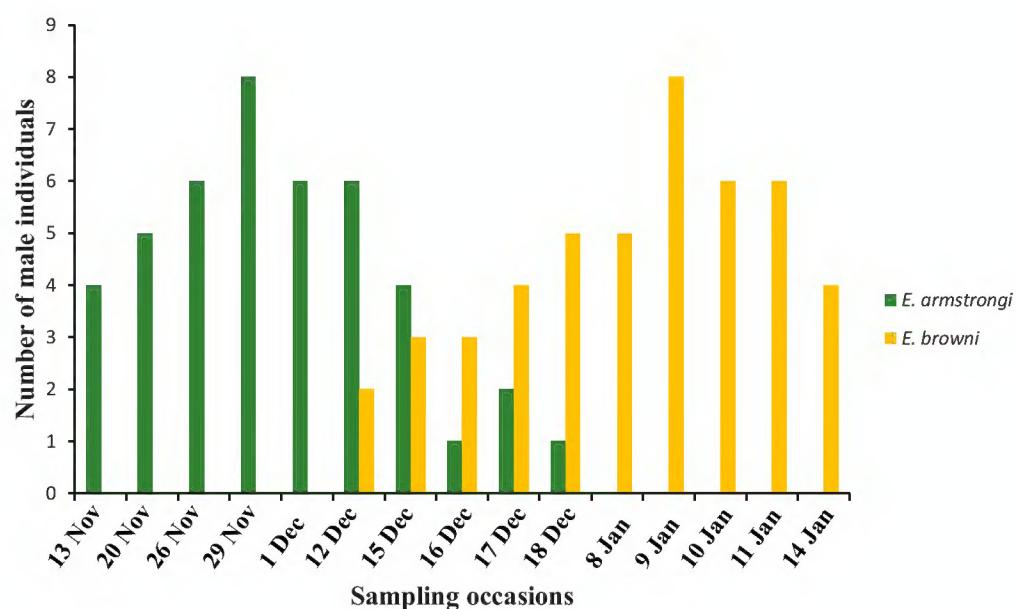


Fig. 4. Variation in number of male *Eremidium armstrongi* and *Eremidium browni* counted in quadrats over time.

Table 3. Mean number (over five sampling occasions) of adult *Eremidium armstrongi* and *Eremidium browni* counted and Braun-Blanquet plant cover-abundance in each quadrat. Forest margin quadrat numbers and data are italicized. Refer to Table 1 for explanation of the symbols.

Quadrat number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Degree of constancy
Mean no. <i>E. armstrongi</i>	0.8	0.6	0.4	0	4	0.2	0.2	0.4	0	0.6	1.2	0	0.2	0.4	0	0	3	0	0.4	0.4	0.6	0	0.2	0	0	0.6	0.2	
Mean no. <i>E. browni</i>	0.4	0.8	0.4	0	3.8	0.2	0.2	1	0.2	0.2	0.4	0	0.6	1.6	0	0	2	0.4	0.2	0	0	0	0.2	0	0	0.8	0	
Plant species																												
<i>Plectranthus laxiflorus</i>	+				1						4						3		1	+								6
<i>Monopsis stellarioides</i>	+																+											2
<i>Miscanthus capensis</i>	2																											1
<i>Prosphytochloa prehensis</i>	4																											1
<i>Cheilanthes viridis</i> vars	1				+																							2
<i>Impatiens hochstetteri</i>		3	2		+	+	2	+	1			+		1				+	1		1	+	+	+	+	r	+	18
<i>Hypoestes forskaolii</i>		r		+					3		1		+					+	2	+	2		1		1	2	2	13
<i>Asparagus plumosus</i>		+				r																						2
<i>Piper capense</i>		1	r												+	r				+			2	r	+		r	9
<i>Isoglossa cooperi</i>		2	1																									2
<i>Justicia campylostemon</i>			1			1	1								+			+										5
<i>Desmodium repandum</i>			+						+			+			+	r							+	r				7
<i>Dioscorea sylvatica</i>			1	1			+																					3
<i>Tricalysia lanceolata</i>			r	+																								2
<i>Polystichum trankeiense</i>				1	+			+	2																	2		5
<i>Poaceae</i>					5			+																				2
<i>Centella asiatica</i>					2												1		+									3
<i>Sanicula elata</i>						+		+															2					3
<i>Cyperus sphaerospermus</i>					2																							1
<i>Crassula c.f. pellucida</i>								+				r		1					2				r			2		6
<i>Achyranthes aspera</i>								+																				1
<i>Oplismenus hirtellus</i>									1					+					+					1				4
<i>Tradescantia fluminensis</i>										3			3					1	1	5	r	5						7
<i>Diclis reptans</i>														5			1									+		3
<i>Thunbergia alata</i>														1			2											2
<i>Selaginella kraussiana</i>															1							r	+		1	+		5
Bare ground		1	1	5		3	5	5	2	3		5	3		5	5					2		3	5	5	2		17

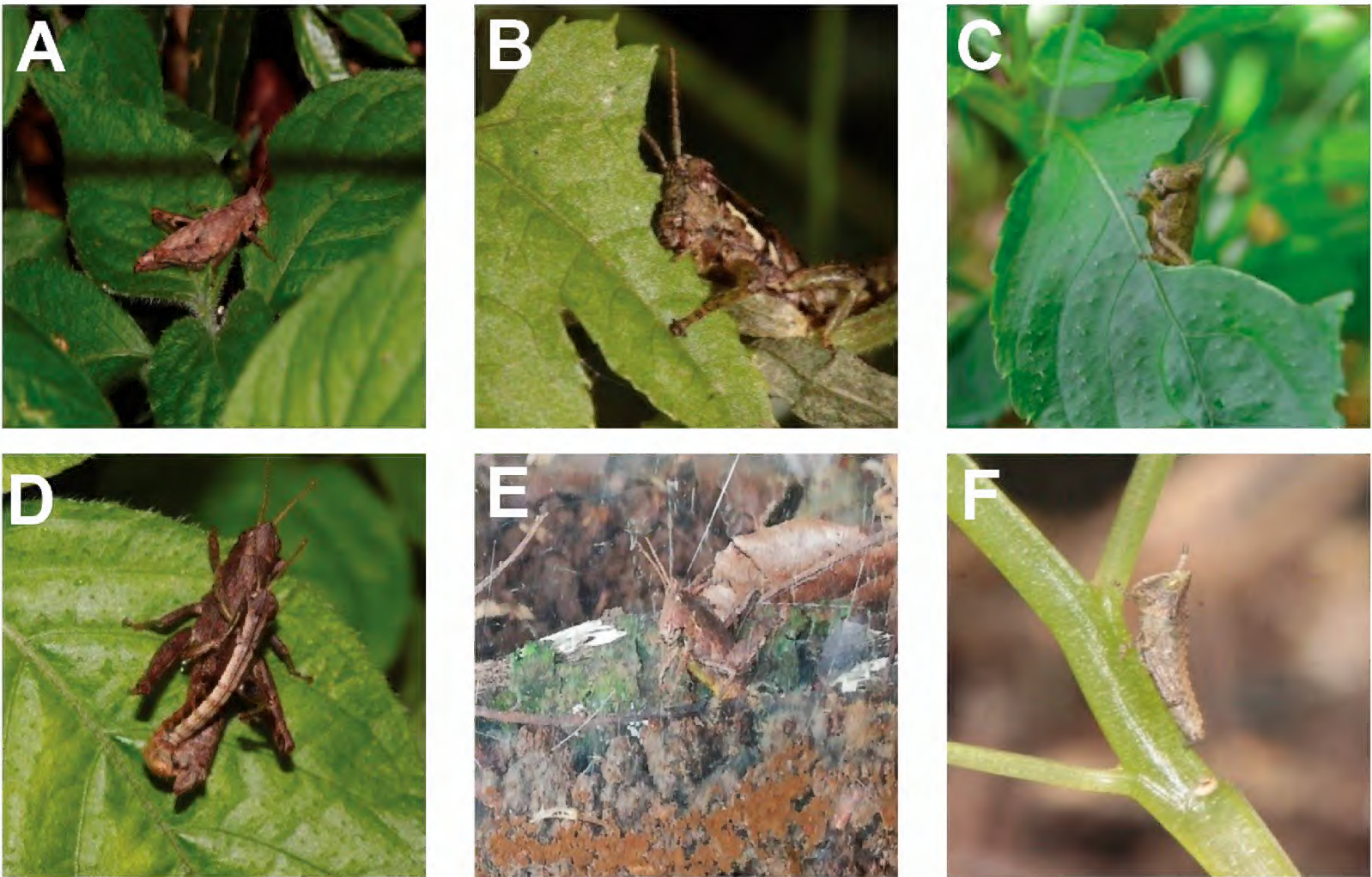


Fig. 5. *Eremidium armstrongi* female feeding on *Hypoestes forskaolii* (A), *Eremidium armstrongi* male feeding on *Diplocyclos palmatus* (B), *Eremidium* species female feeding on *Impatiens hochstetteri* (C), *Eremidium browni* mating (D), *Eremidium browni* female laying her eggs in the terrarium (E), and *Eremidium browni* nymph hatched in terrarium (F).



Fig. 6. Extent of the distribution of *Eremidium* grasshoppers into the grassland.

forest margin and received a fair amount of sunlight. It was noted that quadrat 17 was similar to quadrat 5, which was located on the forest margin and had no bare ground. Between 25–50% of the quadrat was covered by *Plectranthus laxiflorus* Benth. and 6–25% by *Thunbergia alata* Bojer ex Sims (Table 3; Fig. 5), which received a fair amount of sunlight. Most of the remaining quadrats in which either *E. armstrongi* or *E. browni* were observed contained the food plants *Impatiens hochstetteri* Warb. or *Hypoestes forskalii* (Vahl) R.Br. or both (Table 3), while quadrats 1 and 2 received a fair amount of sunlight. Another recorded food plant species, *Diplocyclos palmatus* (L.) C.Jeffrey, was not found in any of the quadrats. Most of the quadrats where no *Eremidium* species were observed had a relatively high percentage cover of bare ground (Table 3). The female *E. browni* in the terrarium was observed laying eggs in the soil (Fig. 5).

Distribution into the grassland.—Fig. 6 indicates the 12 transects that were sampled and the positions of *Eremidium* grasshoppers that were found along these transects over the three sampling days. The sampling area included both grassland and forest. Only one male individual was observed along each of transects 1 and 4, two along transect 5, three along each of transects 7 and 8, four along transect 12, six along transect 6, and seven along transect 9. No individual was found along transects 3, 10, and 11. Transect 9 was located at the margin of the forest. The *Eremidium* grasshoppers recorded along transect 6 were at the margin of the forest, and those along transect 12 were in the forest. No individual was found in the grassland interior (Fig. 6).

Discussion

Grasshopper diversity and populations in any area are influenced by topography, vegetation, and soil (Lockwood and Lockwood 2008). They respond to a combination of interacting abiotic and biotic factors that vary over time and space (Branson 2008). However, the direct, indirect, and interacting effects of host vegetation, competition, weather conditions, and other factors on grasshopper population dynamics are still poorly understood (Skinner and Child 2000, Branson 2008). There has been much debate

between ecologists about the role of intrinsic and extrinsic factors controlling population dynamics (Ritchie 1996). Grasshoppers show variations in their life history, with each species responding differently to these factors (Branson 2004). According to Latchininsky et al. (2011), general grasshopper distribution trends for different regions have been described. However, the processes and factors affecting grasshopper species richness patterns at the different scales are still being elucidated. Local distribution trends have been discussed with regards to grasshopper diversity in relation to vegetative species composition, habitat structure (Latchininsky et al. 2011), and the overall microhabitat of the species (e.g., Joern 1982). Complex interactions between competing necessities influence habitat selection behavior (Ahnesjö and Forsman 2006), and the use of resources, such as food and microhabitats, among grasshopper species is influenced by biotic associations (Joern 1979).

Most grasshopper species have specific microhabitat preferences. These preferences are based on the multiple abiotic and biotic factors that make up the microhabitat. Some of these factors include resource availability (e.g., food or nutrients), microclimate variations (e.g., light intensity, temperature, humidity, and precipitation), structural qualities, suitable hiding places, predation, and competition (Joern 1982, Ahnesjö and Forsman 2006). For grasshoppers, some abiotic factors that influence microhabitat utilization and population size are microclimate, plant structure, plant species richness and abundance, soil characteristics, availability of acceptable oviposition sites and food plants, and suitable hiding places. Hemp and Hemp (2003) used phytosociological relevés, applying the Braun-Blanquet method to ascertain the grasshopper coenoses in the plant communities distinguished in the high-altitude grasslands on Mount Kilimanjaro. They could also determine the microhabitat preferences of species from the data. Only a few studies have shown evidence that biotic factors, such as predation and competition, influence microhabitat selection (Joern 1982).

According to Joern and Klucas (1993), wherever there are herbivorous insects such as grasshoppers, food may become limited, resulting in competitive interactions, something which is of interest yet remains poorly understood. The congeners *E. armstrongi* and *E. browni* are similar in their appearance but also in their mi-

crohabitat preferences and densities. Since these two species share the same microhabitat and possibly food source, they may avoid potentially adverse interaction through differences in phenology, as indicated by the adult male numbers over time (Fig. 4). Competition for resources is a possible reason why *E. armstrongi* and *E. browni* illustrate a peak number of adult male individuals (and, by extension, adult females) when only a single species is present, allowing sympatry of two very similar species. The adults of *E. armstrongi* were observed in the field between October and December 2018, while the adults of *E. browni* were observed between December and February 2019. The number of adult individuals of *E. armstrongi* and *E. browni* were similar in the sampled habitat area (Table 1), with a slight difference in the recorded male to female ratio.

General feeding behavior in grasshoppers, such as food plant specificity, number of taxa in the diet, and the type of vegetation they feed on, is varied (Joern 1983), with most grasshopper species feeding selectively on a variety of plant species from different families (Sword and Dopman 1999), but preference is evident (Joern 1979). Such grasshoppers are referred to as polyphagous, and this has been seen at an individual, population, and species level (Sword and Dopman 1999). Work done by Rowell (1978) suggested that this view is true for grasshoppers found in the temperate zone, and further studies show a greater degree of specificity in grasshoppers of the tropic zones. *Eremidium* species are temperate zone grasshoppers that feed on plants from different families (Fig. 5). At Doreen Clark Nature Reserve, they displayed some level of preference by feeding on soft green vegetation while apparently avoiding vegetation with waxy and sticky surfaces. They were observed feeding on *Impatiens hochstetteri* Warb. (family: Balsaminaceae), *Hypoestes forskoolii* (Vahl) R.Br. (family: Acanthaceae), and *Diplocyclos palmatus* (L.) C.Jeffrey (family: Cucurbitaceae). Observations of feeding by *E. armstrongi* and *E. browni* were too few to determine whether they differ in the plant species in their diets, and the method used does not allow extrapolation to a general conclusion.

Eremidium grasshoppers were only found along the forest-grassland edge and into the forest interior, probably as a result of particular microhabitat requirements. The perceived differences in microhabitat between the forest interior, its margin, and grassland include vegetation composition and structure, light intensity, temperature, and soil compactness. The grassland interior consists of, *inter alia*, tall, hairy grasses containing relatively large amounts of silica in the body structure and more compacted soils exposed to direct weather conditions (light intensity, temperature, and precipitation). The forest floor, in contrast, consists of soft green vegetation, moist soft soils, and dappled sunlight. The microhabitat in the sampled area was suitable for *Eremidium* grasshoppers, but more suitable towards the margin of the forest (Table 3), perhaps owing to the greater availability of sunlight. This area may be thermally suitable for egg production, as mating has been observed at the edge on many occasions. Temperature plays an important role in the fitness and survival of grasshoppers; since grasshoppers are ectotherms, their body temperature influences the activities, ecology and, eventually, overall fitness and development of an individual (Kemp 1986, Willott and Hassall 1998, Ahnesjö and Forsman 2006). Therefore, grasshoppers need to select thermally suitable microhabitats (Ahnesjö and Forsman 2006). In the forest, the canopy cover provides shade with patches of sunlight that filters through to the forest floor and that the *Eremidium* grasshoppers can use to regulate their body temperatures.

Grasshoppers select areas that best suit all their requirements because some microhabitats may provide one factor (e.g., shelter from predators) but may lack other important factors (e.g.,

suitable temperatures, foodplants) needed by the species for survival (Ahnesjö and Forsman 2006). *Eremidium* grasshoppers were found in quadrats that had food plants and bare ground and that received some sunlight for thermoregulation. Depending on the species, grasshopper eggs are laid in the soil where conditions are suitable for growth (Dempster 1963, Lockwood and Lockwood 2008), with a female producing one or more pods containing 3 to 200 eggs each (Lockwood and Lockwood 2008). A female *E. browni* laid eggs in the soil of an *ex situ* terrarium, which were determined from the date of appearance of nymphs in the terrarium (Fig. 5) to take approximately two months to hatch.

Conclusion

Eremidium armstrongi and *E. browni* are two recently described species of grasshoppers; to conserve them for future generations, it is important to understand their life histories and ecology. The two species are very similar, with no significant difference in abundances. Both species occupy the same specific microhabitat with a short period of overlap. Both *E. armstrongi* and *E. browni* are selective for microhabitat and were found to be most abundant along the margin of the forest, but also occurred in the forest interior. Food plants included one species in each of three families in the sampled area, but more observations on feeding are needed to determine whether the two *Eremidium* species differ in diet. Further research needs to be done to improve understanding of the two species, especially in terms of diet and reproductive behavior. Diagnostic features of the adult females of *E. armstrongi* and *E. browni* that can be easily seen in the field should be elucidated to enable researchers to tell them apart more easily.

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